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   L1: (39) steering same motor same reluctance  
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	U	1	Document ID	Issue Date	Pages	Title	Current OR	Current XRef
8	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6107767 A	20000822	20	Electric assist steering system having an improved	318/561	318/432; 318/623;
9	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6068078 A	20000530	8	Electric steering system	180/446	318/489; 701/41
10	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6046560 A	20000404	21	Electric assist steering system having an improved	318/432	180/443; 180/446;
11	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6008599 A	19991228	18	Method and apparatus for controlling an electric	318/254	180/446; 318/599;
12	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5998952 A	19991207	18	Method and apparatus for	318/432	318/696

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DOCUMENT-IDENTIFIER: US 4896089 A  
TITLE: Fault management system for a switched reluctance motor

KWIC

**BSMR:**  
In a typical switched reluctance motor, pole excitation windings on directly opposite stator poles are connected in series aiding to achieve balanced magnetic and mechanical operation. In particular, leakage flux is minimized for maximum utilization of the available ampere-turns, and the radial magnetic forces on the rotor cancel, thus resulting in minimum shaft deflection and vibration. Therefore, there are effectively a number of separate circuits equal to one-half the number of stator poles, the circuits being spatially, ohmically, and magnetically isolated from each other. The present invention utilizes the characteristic independence of the motor phase circuits as the basis for a fault-tolerant drive scheme. Such a fault-tolerant motor drive would be particularly useful in aerospace applications, including fuel pumps and electric generators and the like, for which a motor should continue operating, and also be startable, in spite of a phase fault. Another exemplary application is in automotive power steering.

United States Patent (11)  
Kihman et al.

(11) Patent Number: 4,896,089  
(45) Date of Patent: Jan. 23, 1990

(54) FAULT MANAGEMENT SYSTEM FOR A SWITCHED RELUCTANCE MOTOR

(72) Inventors: Gerald S. Kihman; Stephen B. Macklin, both of Schenectady; Charles M. Stephens, Pattersonville, all of N.Y.  
(73) Assignee: General Electric Company, Schenectady, N.Y.

(21) Appl. No.: 884,185  
(22) Filed: Jan. 21, 1989  
(23) Int. Cl.: H02P 6/00  
(24) U.S. Cl.: 318/430, 318/436  
(25) Field of Search: 318/136, 204, 430, 434, 318/434, 701, 704, 707

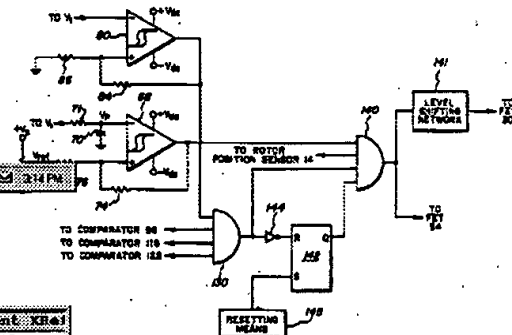
(56) References Cited  
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4,194,442 4/1980 Pohl 318/430 X  
4,324,968 6/1980 Ziegler et al. 318/430 X

4,324,968 6/1980 Langley et al. 318/234  
4,378,723 3/1981 Tiedeman et al. 318/234  
4,380,845 6/1981 Jones 318/254  
4,423,128 12/1980 Tansler 318/701

Primary Examiner—Bentley Ro  
Attorney, Agent or Firm—J. M. Broadbent, James C. Davis, Jr., Marvin Snyder

**ABSTRACT**  
A fault management system for a switched reluctance motor detects faults through phase current differential sensing and phase flux differential sensing and isolates any faults by deactivating any failed phase. Motor operation continues through the remaining phases. A speed control circuit maintains the normal operating speed of the motor, despite the deactivation of one or more phases. Restarting the motor when stopped in a "dead zone" caused by a failed phase is accomplished by using the known phases to generate negative torque to move the rotor out of the dead zone.

24 Claims, 7 Drawing Sheets



		Document ID	Issue Date	Pages	Title	Current OR	Current KR
1	<input type="checkbox"/>	US 6373211 B1	20020416	20	Extended speed range operation of permanent magnets	319/432	318/443; 318/446
2	<input type="checkbox"/>	US 6329782 B1	20011211	15	Method and apparatus for robust generation of an index	318/727	318/138; 318/254
3	<input type="checkbox"/>	US 6166464 A	20001226	14	Power module	310/68R	310/68D
4	<input type="checkbox"/>	US 5743352 A	19980428	6	Electrically-actuated power steering system	180/446	
5	<input type="checkbox"/>	US 5740880 A	19980421	9	Speed tracking of induced armature field in electric p	180/446	318/718; 318/805
6	<input checked="" type="checkbox"/>	US 4896089 A	19900123	10	Fault management system for a switched reluctance motor	318/701	318/234; 318/254

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steering w/  
switch reluctance motors

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1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6373211 B1	20020416	20	Extended speed range operation of permanent	318/432	180/443; 180/446;
2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6329782 B1	20011211	15	Method and apparatus for robust generation of an	318/727	318/138; 318/254;
3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6338016 B1	20020108	11	Method and apparatus for detecting a motor stall	701/43	180/443; 180/446;
4	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6295879 B1	20011002	13	Torque sensing apparatus for an electric assist steering	73/862.08	180/444
5	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6166464 A	20001226	14	Power module	310/68R	310/68D
6	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6144137 A	20001107	9	Electric motor assembly for a vehicle steering system	310/258	310/51; 310/89
7	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6138596 A	20001031	10	Damped steering mechanism for a watercraft	114/144R	114/150; 280/272;
8	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6107767 A	20000822	20	Electric assist steering system having an improved	318/561	318/432; 318/623;
9	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6068078 A	20000530	8	Electric steering system	180/446	318/489; 701/41
10	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6046560 A	20000404	21	Electric assist steering system having an improved	318/432	180/443; 180/446;
11	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 6008599 A	19991228	18	Method and apparatus for controlling an electric	318/254	180/446; 318/599;
12	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5998952 A	19991207	18	Method and apparatus for reducing torque ripple in an	318/432	318/696
13	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5992556 A	19991130	10	Method and apparatus for damping control of an	180/446	701/41
14	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5979587 A	19991109	8	Electrically assisted power steering apparatus	180/446	318/433; 318/621
15	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5971094 A	19991026	11	Electric power steering device	180/444	
16	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5786754 A	19980728	15	Method and apparatus for electronically cancelling a	340/476	180/401; 340/475;
17	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5743352 A	19980428	6	Electrically-actuated power steering system	180/446	
18	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5743351 A	19980428	10	Method and apparatus for controlling an electric	180/446	701/41
19	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5740880 A	19980421	9	Speed tracking of induced armature field in electric	180/446	318/718; 318/805;
20	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5738183 A	19980414	12	Motor operated power steering device	180/444	74/388PS
21	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5625239 A	19970429	11	Method and apparatus for sensing relative position	310/68B	310/171; 324/207.17;
22	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5623409 A	19970422	17	Method and apparatus for non-linear damping of an	701/41	180/443; 180/446;
23	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5568389 A	19961022	10	Method and apparatus for controlling an electric	701/41	180/446
24	<input type="checkbox"/>	<input checked="" type="checkbox"/>	US 5523637 A	19960604	6	Permanent magnet electrical	310/156.47	310/152.
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steering w/  
Variable reluctance motors  
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